MEMORANDUM

TO: Julian Jones, EPA/APPCD

FROM: Darcy Campbell, Radian Corporation

DATE: July 12, 1995

SUBJECT: Model City HAP Analysis

Introduction

The U.S. Environmental Protection Agency (EPA) has implemented the Urban Area Source Program (UASP) required under Title III of the Clean Air Act Amendments (CAAA) of 1990. To meet the goals of the CAAA, the EPA is implementing a national strategy designed to (1) identify 30 or more hazardous air pollutants (HAPs) that represent the "greatest threat to public health in the largest number of urban areas," (2) regulate stationary area sources that account for 90 percent of the emissions of these HAPs, and (3) reduce the cancer incidence associated with these sources by 75 percent. Area sources are defined in the CAAA as emitting less than 10 tons per year (tpy) of a single HAP and less than 25 tpy of all HAPs combined.

The EPA's Air Pollution Prevention and Control Division is assisting the Office of Air Quality Planning and Standards in the UASP by conducting a HAP emissions research program. The emissions research program began with the development of area source HAP inventories for Chicago, Seattle, and Houston. These inventories were primarily developed by combining HAP emission factors and speciation profiles with the activity data and estimated volatile organic compound (VOC) emissions provided in the State Implementation Plan (SIP) area source emissions inventories for each city. Because the SIP inventories focus on VOC sources, special effort was made to gather information on sources of non-volatile HAPs in developing the model city HAP inventory. Manufacturing facilities such as primary and secondary metal manufacturers and industrial surface coaters are included in the model city HAP inventory.

In this memo, portions of the three area source HAP emissions inventories are combined to create a complete area source HAP emissions inventory for a "model" city in the U.S. The model city inventory is more complete than any of the three inventories in terms of source category coverage. The activity data used to develop the model city inventory was also adjusted to represent a typical large urban area, not necessarily any of the three studied previously. For example, there are more small chemical manufacturing facilities in Houston than in most other urban areas in the country. In the model city inventory, the emissions estimates for this source category were derived from Houston's inventory, but scaled down by 50%. Activity-data adjustments were made by reviewing the Chicago, Seattle, and Houston SIP inventories, as well as the NY City SIP inventory which is available in-house at Radian. Other information sources for activity data updates were a memo prepared by Radian Corporation for the EPA's Emission Factor Improvement Group (Adams, 1994) which summarized area source SIP inventory data reported in AIRS/AMS and information on manufacturers published by SRI International and the Census Bureau.

The estimated model city HAP emissions are also combined with health effects data to develop "health hazard indices." These indices were developed as a first step to identifying the HAP's threat to public health. This evaluation is not complete in its consideration of risks to the public; complete exposure and risk assessments have not been conducted. No actual "risk estimates" have been developed in this project; rather, a simple ranking schemes based on toxicity-weighted emissions are used as tools for determining the relative importance of area source HAP emissions.

Methods

The Houston area source HAP emissions inventory was used as the starting point for the model city inventory because it was the most comprehensive of the three inventories. The population of the model city is therefore almost 3 million people. In addition to the area source categories covered in the SIP emissions inventory, the Houston HAP inventory included several area source manufacturing source categories. The HAP emissions estimates for these facilities were developed by Radian Corporation, the Texas Natural Resource Conservation Commission, and the City of Houston Bureau of Air Quality through phone surveys and site visits. The manufacturing source categories were:

- Cultured marble manufacturers;
- Ship and boat repair and manufacturing facilities;
- Metal plating facilities, and
- Industrial surface coating facilities.

HAP estimates were also prepared for oil and gas production support facilities, but these types of facilities are likely to be significant only in cities with extensive oil and gas production activities rather than a typical urban area. This source category is not included in the model city inventory.

For ship and boat repair and manufacturing facilities, emission estimates were adjusted downward by 67% because of the prevalence of these facilities in the Houston area. The emissions were adjusted based on information on number of facilities in each state provided in the EPA report Assessment of VOC Emissions from Fiberglass Boat Manufacturing (EPA, 1990) and the Census of Manufactures (U.S. Department of Commerce, 1991). A similar downward adjustment (of 65%) was applied to the cultured marble manufacturing emissions. Based on anecdotal evidence, it is expected that there is a higher number of these facilities in Houston compared to an average urban area, possibly due to the large number of chemical manufacturers. While there is not census of manufacturing information specific to cultured marble, an adjustment was made based on the number of facilities in the "Miscellaneous Plastics Products" category in the Census of Manufactures (U.S. Department of Commerce, 1991).

The Texas Point Source Database was also accessed to obtain emissions data for additional small point source facilities in Houston which fall below the 10/25 tpy area source cutoff. Emissions data were obtained in this manner for chemical manufacturers, organic chemical storage/transport facilities, solvent extraction facilities, and petroleum refining and natural gas production. Data for petroleum refining and natural gas production were not included in the area source inventory because these sources are not likely to be significant in most urban areas. The Houston emissions data for the other three source categories--chemical manufacturing, organic chemical storage/transportation, and solvent extraction facilities--were scaled down by 50% to represent more average urban conditions. The 50% value was selected by reviewing the number of facilities listed for several states in the SRI International report Directory of Chemical Producers (SRI International, 1994).

Emission estimates for forest fires in the model city were developed from the Seattle inventory. The Seattle activity data for this source were adjusted downward to reflect more typical urban conditions for the model city. The activity adjustments made were based on information presented in the Houston, Chicago, and New York City SIP inventories, but there was a very large range in the activity data between the cities.

The Houston activity data for woodstoves and fireplaces were adjusted upward based on information in the Seattle and New York City SIP inventories.

Two other adjustments worth mentioning are for auto refinishing and dry cleaning establishments. For auto refinishing, the Houston inventory estimated HAP emissions were based on a VOC emission factor of 0.26 lbs/person based on information gathered by surveying a limited number of facilities. In the Chicago and Seattle inventories a VOC emission factor of 2.3 lbs/person was used based on SIP inventory guidance provided by the EPA (EPA, 1991). Because of the large difference between these two values, SIP inventories prepared for other ozone nonattainment areas were evaluated. Most used a VOC emission factor of 2.3 lbs/person. The SIP inventory prepared for New York City, however, used a VOC emission factor developed from information published by the EPA, Frost and Sullivan (1989), and SRI International. The *per capita* VOC emission factor of 0.9 lbs/person was developed based on gallons of coating used and an assumed VOC content of the coatings of 6.2 lbs/gallon. The value of 0.9 lbs VOC/person was used for the model city because it seems more reasonable than either the Houston or Chicago/Seattle emission factors.

For dry cleaning establishments, TNRCC conducted a survey to evaluate perchloroethylene use. Because a significant number of facilities were surveyed (over 100), the survey results were thought to be more representative (or up-to-date) of the dry cleaning industry than the information provided in EPA SIP guidance documents. A perchloroethylene speciation profile of 73.75% was therefore used to estimate HAP emissions for this source category in the model city.

Finally, all of the area sources in the model city are assumed to be uncontrolled sources in this inventory. This decision was made because the CAAA instructs EPA to identify area source categories for research and development of regulations; by assuming all emission sources to be uncontrolled source categories that are not regulated in all urban areas can be identified.

Estimated Emissions

Table 1 shows the estimated area source emissions and the contributing source categories for the model city. 1,1,1-trichloroethylene is the top-emitted HAP with total emissions of 2440 tons per year (tpy). Surface cleaning (degreasing) is the source of most of these emissions. Perchloroethylene emissions of 2330 tpy are from dry cleaning (2080 tpy) and surface cleaning (245 tpy). Toluene emissions total 1635 tpy, from numerous source categories such as graphic arts (225 tpy), consumer and commercial products (320 tpy), auto refinishing (500 tpy), and gasoline distribution (200 tpy combined) and a host of less significant sources. Structure fires are the only source of hydrogen cyanide in the model city inventory, with emissions estimated at 1070 tpy. The quality of this estimate, however, is questionable. Emissions data from only one test were used to develop the estimate for this category; more research is needed.

Other HAPs that are emitted in significant amounts are trichloroethylene (890 tpy) and methylene chloride (690 tpy) from surface cleaning operations. Hexane (630 tpy), xylene (490 tpy), and benzene (430 tpy) are emitted from a number of source categories including gasoline distribution, architectural coatings (for hexane), graphic arts and auto refinishing (for xylene), and residential wood burning (for benzene).

In terms of total HAP emissions, some source categories that stand out in addition to those mentioned above are: marine vessel loading (285 tpy), traffic markings (162 tpy), and landfills (135 tpy).

Development of Health Hazard Indices

The next step in this project was to rank the estimated HAP emissions based on more than just total emissions. Different ranking schemes were used for carcinogens (cancer causing agents) and noncarcinogens. The ranking schemes were selected based on discussions with contacts in EPA's National Health and Environmental Effects Research Laboratory.

For carcinogens, the inverse of the ED_{10} was used to develop the health hazard indices. An ED_{10} is the estimated dose associated with an increased cancer incidence of 10 percent. The ED_{10} values are taken from EPA (1994). The term "health hazard index" is used here for the combined emissions and ED_{10} values.

The EPA's National Health and Environmental Effects Research Laboratory compiled information on the toxicity of noncarcinogenic HAPs to prioritize research in support of the 1990 CAAA (EPA, 1993). Data on the effects of noncarcinogens were taken from EPA and Agency for Toxic Substances and Disease Registry documents and data files and from the Hazardous Substances Data Bank of the National Library of Medicine. EPA information sources included the Integrated Risk Information System, Health Assessment Documents, Drinking Water Criteria Documents, and Health Effects Assessment Summary Tables.

The EPA only summarized data from inhalation studies; the report identified the lowest dose producing an effect (LOAEL) and the highest ineffective dose (NOAEL). The inverse of these values were combined with the model city emissions data to develop noncarcinogenic health hazard indices.

Results of Health Hazard Analysis

Table 2 presents the model city carcinogen hazard indices developed for this project. Chromium compounds rank the highest, but this is a very conservative estimate; adjustments are needed if information can be gathered on the amount of chromium emitted that is actually Cr+6. This assumes all the chromium is in the hexavalent state. Most of the chromium in the model city inventory is from metal plating facilities. POM emitted from residential wood burning ranks second on the carcinogen hazard index. Formaldehyde emissions primarily from fossil fuel combustion and structure fires are ranked third, followed by benzene. Benzene is emitted from numerous source categories, including marine vessel loading, gasoline distribution, and residential wood burning.

Table 3 presents the model city noncarcinogen hazard indices. It should be noted that some carcinogens are included on this table because in addition to causing cancer, some HAPs have been found by EPA to cause other types of health effects. Formaldehyde, benzene, and perchloroethylene are examples.

Acrolein is the highest-ranked noncarcinogen shown in Table 3. Other HAPs are emitted in much greater amounts, but the low LOAEL/NOAEL for acrolein gives it the highest hazard index. The majority of acrolein is thought to be emitted from structure fires; as mentioned previously, this estimate needs refinement. Toluene ranks second on the noncarcinogen hazard index, and is emitted from gasoline distribution, graphic arts, consumer and commercial products, traffic markings, auto refinishing, and several other source categories. Formaldehyde is also emitted from many area source categories in the model city inventory and ranks third on the noncarcinogen hazard index. Like acrolein, however, structure fires are shown to emit the majority of formaldehyde, and the emission estimate is based on very limited test data.

Conclusions

Some conclusions that can be drawn from the information presented here that pertain to the requirements in the CAAA are that this simplistic model city area source inventory covers the source categories that are present in most urban areas, and represents the source categories in a generic way because adjustments were made to eliminate some of the regional influences that were present in the Chicago, Puget Sound, and Houston HAP inventories. By combining the emissions estimates with a measure of toxicity, the resulting hazard indices can be used to identify HAPs and area source categories that should be investigated further.

Many of the area source categories that stand out here as important HAP sources in terms of total emissions or health hazard index are already under review by EPA for the development of regulations. Some of the regulations are directed toward VOC controls in nonattainment areas only, others will be national regulations on HAP emissions. These source categories include:

- Surface cleaning;
- Dry cleaning;
- Consumer and commercial products;
- Auto refinishing;
- Chromium electroplating;
- Architectural coatings; and
- Municipal landfills.

Some upcoming HAP regulations that are currently slated to cover only major sources are for gasoline distribution (stage I), marine vessel loading, institutional/commercial boilers, and printing and publishing (graphic arts). Area sources in these categories should be examined for the inclusion in the regulations.

A cursory review of EPA's schedule for developing regulations reveals that none are planned for the following area source categories that have been shown here to be important sources of HAPs in the model city:

- Traffic coatings;
- Residential fossil fuel combustion; and
- Gasoline distribution (stage II).

Emissions from woodstoves should decrease as new stoves that are certified to meet EPA emission standards are purchased to replace older ones. Structure fires is one area source category where more research is warranted, if only to better quantify the source of HAPs detected with ambient monitoring.

Finally, it is important to note that the results presented here are only as good as the available data. The data available for area source HAP emissions inventories are generally not as good as those available for major sources, which are often based on facility-specific information. Research conducted on some area source categories has resulted in the development of relatively high quality emission factors or speciation profiles, but there are limited activity data available. For other source categories the activity data are easy to obtain, but more research is needed on the HAP emissions. Combustion sources are an example.

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TABLE 1. SUMMARY OF AREA SOURCE HAP EMISSIONS IN MODEL CITY

HAP	Marine Vessel Loading	Tank Truck Unloading	Vehicle Refueling	Tank Trucks in Transit	Storage Tanks	Gasoline Spillage	Leaking Underground Storage Tanks	Surface Cleaning Operations	Dry Cleaning	Graphic Arts	Cutback Asphalt	Consumer and Commercial Products	Hospital Sterilizers	Traffic Markings
1,1,1-Trichloroethane								2436.03						
Toluene	63.75	65.35	98.47	1.34	8.95	6.27	23.05			226.35	0.20	322.42		118.74
Hydrogen Cyanide														
Perchloroethylene (tetrachloroethylene)								245.86	2080.34					
Xylene	22.57	25.13	37.87	0.52	3.44	2.41	8.87			187.10	0.37			8.52
Trichloroethylene								887.22						
Methylene Chloride								459.64				125.51		
Hexane	109.28	80.43	121.19	1.65	11.02	7.71	28.37							
Hydrochloric Acid														
Styrene														4.84
Glycol ethers (total)										341.61				0.67
Methanol												192.84		
Methyl Ethyl Ketone										69.48				24.78
p-Dichlorobenzene												148.46		
Acrolein														
Benzene	49.30	45.24	68.17	0.93	6.20	4.34	15.96							
Ethylene Glycol												88.63		1.90
Ethylbenzene	4.51	5.03	7.57	0.10	0.69	0.48	1.77			11.99	0.07			0.15
2,2,4-Trimethylpentane	36.12	40.21	60.60	0.83	5.51	3.86	14.19							
Formaldehyde														
Chromium														
Methyl Methacrylate														0.82
Ethylene Oxide													10.93	
Carbonyl Sulfide														
Ethylene Dichloride														
Vinyl Chloride														
Carbon Tetrachloride														0.26
Chlorine														
Ether, Tert-Butyl-Methyl														
Ethyl Chloride														
Methyl Isobutyl Ketone														0.03
Dimethyl Formamide														
Propylene Oxide														1.89
Methyl Chloride														
1,3-Butadiene														
Aniline														
Acrylonitrile														
Hydrogen Sulfide														
Ethylene Dibromide														
Naphthalene														0.05

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Vinyl Acetate 41														
1,2,4- Trichlorobenzene														
Dimethyl phthalate														
Phenol														
1,1-Dichloroethane (ethylidene dichloride) 45														
2-Nitropropane														
POM														
Chloroform														
Triethylamine														
Chlorotoluene, A-														
Acrylic Acid														
1,2-Dichloroethane														
Carbon Disulfide														
Hydrofluoric Acid														
Epichlorohydrin 55														
Phthalic Anhydride														
Toluidine, O-														
Acetaldehyde														
Maleic Anhydride														
Nickel														
1,1,2,2-Tetrachloroethane														
Chlorobenzene														
Hydrogen Chloride														
1,1-Dichloroethene (vinylidene chloride)														
Biphenyl														
1,2-Dichloropropane (propylene dichloride)														
Cumene														0.03
1,4-Dioxane														
Lead														
1,1,2-Trichloroethane														
Dichlorobenzene (mixed isomers)														
Acetonitrile														
Anisidine, (O-,P-Isomers)														
Cadmium														
Ethyl Acrylate														
Hydrogen Fluoride														
Diethanolamine														
Manganese														

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HAP	Architectural Coatings	Auto Refinishing	Forest Fires	Structure Fires	Residential Wood Burning	Landfills	Industrial Surface Coating Facilities	Cultured Marble Manufacturers	Boat Manufacturing and Repair	Metal Plating Facilities	Chemical Manufacturing	Organic Chemical Storage/ Transport
1,1,1-Trichloroethane						0.44						0.45
Toluene	59.26	505.07	3.14		81.28	35.38					6.12	2.91
Hydrogen Cyanide				1072.40							0.06	
Perchloroethylene (tetrachloroethylene)						6.92	0.03					
Xylene	29.63	108.23	2.18		22.49	15.79	0.00		0.87		5.83	1.50
Trichloroethylene						3.32					0.38	0.02
Methylene Chloride	82.72					14.74	0.55				2.20	0.80
Hexane	235.89		0.09			6.95					9.37	0.18
Hydrochloric Acid				457.56						5.70		
Styrene							6.52	149.91	0.44			
Glycol ethers (total)												0.08
Methanol	44.44										9.51	2.93
Methyl Ethyl Ketone	63.81	6.68			32.29	6.89		0.00E+00	0.01		1.03	1.14
p-Dichlorobenzene												
Acrolein			1.86	133.45							0.00E+00	
Benzene	4.51		3.15		215.79	2.13					6.07	
Ethylene Glycol	14.36										3.32	0.09
Ethylbenzene	49.00	6.68				5.79	0.00E+00				3.12	0.34
2,2,4-Trimethylpentane												
Formaldehyde			7.24	30.98							1.90	0.01
Chromium					0.00E+00					16.46		
Methyl Methacrylate								9.91				0.14
Ethylene Oxide											4.54	
Carbonyl Sulfide						17.50						
Ethylene Dichloride											7.15	
Vinyl Chloride						5.59					3.75	
Carbon Tetrachloride											6.17	0.05
Chlorine											3.71	0.34
Ether, Tert-Butyl-Methyl											0.41	
Ethyl Chloride	9.02					0.92						
Methyl Isobutyl Ketone	6.84	4.01				1.48					0.11	0.06
Dimethyl Formamide	5.70										1.78	
Propylene Oxide											3.29	
Methyl Chloride	7.52										0.28	
1,3-Butadiene			1.13								2.58	
Aniline											2.45	0.23
Acrylonitrile						4.87					0.20	
Hydrogen Sulfide											0.26	
Ethylene Dibromide											0.90	0.84
Naphthalene											1.69	0.68

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Vinyl Acetate												0.94
1,2,4- Trichlorobenzene											1.39	
Dimethyl phthalate								0.95	0.00E+00			
Phenol											0.98	0.25
1,1-Dichloroethane (ethylidene dichloride)						2.49						
2-Nitropropane											1.13	
POM					80.64							
Chloroform						0.39						0.07
Triethylamine											0.65	
Chlorotoluene, A-											0.65	
Acrylic Acid											0.00	
1,2-Dichloroethane						0.95						
Carbon Disulfide						0.92						
Hydrofluoric Acid											0.37	
Epichlorohydrin												0.01
Phthalic Anhydride											0.33	
Toluidine, O-											0.28	0.00E+00
Acetaldehyde											0.25	
Maleic Anhydride											0.24	
Nickel					1.45E-05							
1,1,2,2-Tetrachloroethane						0.41						
Chlorobenzene						0.27						0.06
Hydrogen Chloride												
1,1-Dichloroethene (vinylidene chloride)						0.26						
Biphenyl											0.00	0.13
1,2-Dichloropropane (propylene dichloride)						0.23						
Cumene											0.07	0.01
1,4-Dioxane												
Lead							0.11					
1,1,2-Trichloroethane						0.16						
Dichlorobenzene (mixed isomers)												
Acetonitrile											0.05	
Anisidine, (O-,P-Isomers)											0.05	0.00E+00
Cadmium					2.28E-05					0.06		
Ethyl Acrylate												
Hydrogen Fluoride												
Diethanolamine											0.02	
Manganese					0.02							
Nickel Compounds												

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Cresol												0.01
Propionaldehyde												
Mercury												
Arsenic												
Cobalt Compounds												
1,2-Butylene Oxide												
Berylium												
Cobalt												
Antimony												
Selenium												
Total CDF												
Dioxins					7.15E-07							
Total CDD												
Furans					5.60E-07							

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HAP	Medical Waste Incineration	Fossil Fuel Combustion Residential	Fossil Fuel Combustion Commercial	POTW's	Primary and Secondary Metal Manufacturing	Solvent Extraction	Total Emissions
1,1,1-Trichloroethane				0.77	2.81	0.05	2440.55
Toluene		3.70	2.64	0.28	0.14	1.11	1635.92
Hydrogen Cyanide							1072.46
Perchloroethylene (tetrachloroethylene)				0.99			2334.14
Xylene		0.00	0.08	0.18		2.95	486.53
Trichloroethylene				0.12		0.04	891.10
Methylene Chloride				0.83		0.42	687.41
Hexane		2.03	1.49		15.25	0.14	631.04
Hydrochloric Acid							463.26
Styrene				0.02			161.73
Glycol ethers (total)						0.44	342.80
Methanol						0.07	249.79
Methyl Ethyl Ketone						0.15	206.26
p-Dichlorobenzene							148.46
Acrolein							135.31
Benzene		7.34	5.08	0.34	0.28	0.01	434.84
Ethylene Glycol						0.95	109.25
Ethylbenzene		0.00	0.01				97.30
2,2,4-Trimethylpentane							161.32
Formaldehyde		17.35	12.68	1.00E-02	0.07	0.04	70.28
Chromium	1.50E-04		0.13				16.59
Methyl Methacrylate						0.38	11.25
Ethylene Oxide						0.03	15.50
Carbonyl Sulfide							17.50
Ethylene Dichloride						0.01	7.16
Vinyl Chloride							9.34
Carbon Tetrachloride				0.08		0.05	6.61
Chlorine	0.04					1.85	5.94
Ether, Tert-Butyl-Methyl						0.03	0.44
Ethyl Chloride							9.94
Methyl Isobutyl Ketone							12.53
Dimethyl Formamide							7.48
Propylene Oxide							5.18
Methyl Chloride							7.80
1,3-Butadiene						0.01	3.72
Aniline							2.68
Acrylonitrile						0.01	5.08
Hydrogen Sulfide							0.26
Ethylene Dibromide							1.74
Naphthalene							2.42

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HAP	Medical Waste Incineration	Fossil Fuel Combustion Residential	Fossil Fuel Combustion Commercial	POTW's	Primary and Secondary Metal Manufacturing	Solvent Extraction	Total Emissions
Vinyl Acetate						0.47	1.41
1,2,4- Trichlorobenzene							1.39
Dimethyl phthalate							0.95
Phenol							1.23
1,1-Dichloroethane (ethylidene dichloride)							2.49
2-Nitropropane							1.13
POM		0.00E+00	0.05				80.69
Chloroform				0.98			1.44
Triethylamine						0.01	0.66
Chlorotoluene, A-							0.65
Acrylic Acid						0.49	0.49
1,2-Dichloroethane							0.95
Carbon Disulfide							0.92
Hydrofluoric Acid						0.04	0.41
Epichlorohydrin						0.35	0.36
Phthalic Anhydride							0.33
Toluidine, O-							0.28
Acetaldehyde							0.25
Maleic Anhydride							0.24
Nickel	1.19E-04		0.44				0.44
1,1,2,2-Tetrachloroethane							0.41
Chlorobenzene		0.00E+00	0.01				0.34
Hydrogen Chloride	0.36						0.36
1,1-Dichloroethene (vinylidene chloride)				0.04			0.30
Biphenyl							0.13
1,2-Dichloropropane (propylene dichloride)							0.23
Cumene							0.11
1,4-Dioxane				0.02			0.02
Lead	0.03		0.02				0.16
1,1,2-Trichloroethane							0.16
Dichlorobenzene (mixed isomers)				0.12			0.12
Acetonitrile							0.05
Anisidine, (O-,P-Isomers)							0.05
Cadmium	1.99E-03		0.03				0.09
Ethyl Acrylate						0.03	0.03
Hydrogen Fluoride	0.05						0.05
Diethanolamine							0.02
Manganese	1.70E-04		0.03				0.05
Nickel Compounds					0.03		0.03

TABLE 1. SUMMARY OF AREA SOURCE HAP EMISSIONS IN MODEL CITY

HAP	Medical Waste Incineration	Fossil Fuel Combustion Residential	Fossil Fuel Combustion Commercial	POTW's	Primary and Secondary Metal Manufacturing	Solvent Extraction	Total Emissions
Cresol							0.01
Propionaldehyde						0.01	0.01
Mercury	0.01		0.01				0.01
Arsenic	5.15E−05		0.01				0.01
Cobalt Compounds					0.01		0.01
1,2−Butylene Oxide					0.01		0.01
Berylium	2.27E−06		0.01				0.01
Cobalt			0.01				0.01
Antimony	1.49E−04		2.00E−03				2.15E−03
Selenium			2.00E−03				2.00E−03
Total CDF	1.79E−06						1.79E−06
Dioxins		9.40E−10					7.16E−07
Total CDD	6.70E−07						6.70E−07
Furans		3.76E−09					5.64E−07

Table 2. Model City Carcinogen Hazard Indices

HAP	Total Emissions	1/ED10	Hazard Index–Carcinogens
Chromium Compounds	16.59	390	6470.10
POM*	80.69	54	4357.37
Formaldehyde	70.28	3	210.84
Benzene	434.84	0.27	117.41
1,3–Butadiene	3.72	8.4	31.25
Trichloroethylene	891.10	0.035	31.19
Perchloroethylene	2334.14	0.012	28.01
Ethylene Oxide	15.50	1.3	20.15
Dichlorobenzene (mixed isomers)	148.58	0.13	19.32
Vinyl Chloride	9.34	1.6	14.94
Acrylonitrile	5.08	2.3	11.68
Methylene Chloride	687.41	0.013	8.94
Cadmium Compounds	0.09	58	5.22
Ethylene Dibromide	1.74	2.1	3.65
Ethylene Dichloride	7.16	0.39	2.79
Dioxins/furans**	3.74E–06	660000	2.47
Carbon Tetrachloride	6.61	0.34	2.25
Arsenic Compounds	0.01	140	1.69
Propylene Oxide	5.18	0.16	0.83
1,1,2,2–Tetrachloroethane	0.41	1.7	0.70
Beryllium Compounds	0.01	80	0.48
Methyl Chloride	7.80	0.052	0.41
1,2–Dichloroethane	0.95	0.39	0.37
1,1–Dichloroethene (vinylidene chloride)	0.30	1.2	0.36
Aniline	2.68	0.13	0.35
1,2–Dichloropropane (propylene dichloride	0.23	0.36	0.08
1,1,2–Trichloroethane	0.16	0.21	0.03
Toluidine, O–	0.28	0.093	0.03
Acetaldehyde	0.25	0.033	0.01
Epichlorohydrin	0.36	0.021	0.01
Ethyl Acrylate	0.03	0.22	0.01
1,4–Dioxane	0.02	0.034	0.00

* ED10 is for B(a)P.
** ED10 is for 2,3,7,8–TCDD.